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EFFECTS OF SUPPLEMENTAL LINGUISTIC CUES ON THE WORD INTELLIGIBILITY OF SEVERELY DYSARTHRIC SPEAKERS

BY

CHRISTINE BELIVEAU

A thesis submitted to the Faculty of Graduate Studies and Research

in partial fulfillment of the requirements for the

degree of Master of Science

in

Speech-Language Pathology

DEPARTMENT OF SPEECH PATHOLOGY AND AUDIOLOGY

Edmonton, Alberta
FALL, 1993

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled **EFFECTS OF SUPPLEMENTAL LINGUISTIC CUES ON THE WORD INTELLIGIBILITY OF SEVERELY DYSARTHRIC SPEAKERS**, submitted by **CHRISTINE BELIVEAU** in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE.**

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18 June 1993

ABSTRACT

Severely dysarthric speakers who are considering an augmentative form of communication may think this option precludes use of their residual speech. Current procedures used to assess speech intelligibility do not address adequately how natural speech might be incorporated into a total communication system for an individual with severe dysarthria. The purpose of this investigation was to determine if either one of two types of linguistic cues (letter & semantic) or a combination of these, increased the speech intelligibility of three speakers with different severity levels of dysarthria. Speech intelligibility was judged by four panels of 10 unfamiliar listeners (N=40) using a word transcription task. A three factor (2x2x3) mixed design was used to determine the effects of two cuing conditions, each with two levels, and severity of dysarthria, having three levels, on speech intelligibility scores expressed as the number of correctly transcribed single words. The three factors and their respective levels were Letter Cue (present/absent), Semantic Cue (present/absent) and Severity Level (profound/severe/moderately severe). Significant main effects were obtained for all three independent variables. A significant first-order interaction was found for Semantic Cue by Speaker Severity, and a significant second-order interaction was found for Letter Cue by Semantic Cue by Speaker Severity. The two linguistic cues were equally effective in enhancing single word intelligibility scores for unfamiliar listeners. No significant interaction was observed for Letter Cue by Semantic Cue. Results are discussed with reference to the most efficient cuing condition for each speaker severity level.

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CHAPTER I

INTRODUCTION

Intelligible speech is a primary goal for all disordered speakers. However, for some patients with severe dysarthria, the probability of developing completely understandable speech is low. Rosenbek and Lapointe (1978, p. 258) stated that "the goal of essentially all dysarthria treatment is not normal speech but compensated intelligibility". In many situations, severely dysarthric individuals who use only speech are unlikely to be independent communicators. In those situations alternate forms of communication may be considered to augment the person's residual speech. Dysarthric speech need not be completely intelligible to be functional for communication. Rather, the individual's residual speech abilities may be considered as one component in a total system of communication. The prevailing view on alternate and augmentative communication is that the communication system for a speech-disabled individual should not be a single technique or aid, but rather a collection of techniques and strategies that the individual uses interchangeably (Vanderheiden & Lloyd, 1986). Although natural speech is superior to alternate forms of communication in rate, efficiency and flexibility (Yorkston, Beukelman & Bell, 1988), non-speech approaches may be adopted without consideration of residual speech abilities because assessment procedures are not available to determine the relative contribution of residual speech abilities to an individual's communication effectiveness. Traditional methods of assessing articulation and intelligibility fail to provide sufficient information to assist in deciding how best to use residual speech. Familiar and unfamiliar listeners generally provide conflicting opinions on how well they understand a dysarthric speaker: Family members may profess to understand most of what is said by the speaker, while less familiar listeners confess to minimal understanding of any spoken message. Currently speech-language pathologists have insufficient information on which to base decisions about the role that residual speech may play in an augmentative communication system or how speech and non-speech options may be combined most effectively for an individual. Comprehensive assessment methods are required for severely disordered speakers with limited intelligibility that accommodate both speech and non-speech options.

CHAPTER II

LITERATURE REVIEW

Speech intelligibility is an issue of general concern in speech pathology. It influences a broad range of conditions that compromise communicative competence including child language and phonological disorders, dyspraxia, dysfluency, hearing impairment, aphasia, cleft palate and dysarthria. Intelligibility is the essential feature of communicative competence (Kent, 1988) and improvement in intelligibility is the primary objective of most speech-language management. It is the joint product of acoustic signals and factors such as context, familiarity, utterance length, word predictability and listener familiarity (Ansel & Kent, 1992). Nevertheless, standardized techniques for describing and measuring intelligibility are not routinely used in the clinical assessment of many conditions that affect communicative competence. If clinical descriptions of intelligibility are acknowledged, they are likely to be informal, subjective, and lacking standardization.

The literature to be reviewed on assessment of speech intelligibility will be presented in three sections. The first provides a description of current methods used to assess intelligibility and a review of studies that have identified factors that can influence clinical judgements of intelligibility. The second summarizes the findings from studies that have attempted to investigate the relationship between error patterns and speech intelligibility. The third section reviews environmental and speech-related factors that have the potential to enhance listener judgements of speech intelligibility. Information reviewed in this final section is considered in relation to cognitive theories of language processing and speech decoding.

2.1 Speech Intelligibility

2.1.1 Measurement of Speech Intelligibility. In this section, definitions of speech intelligibility will be examined, followed by a review of how speech intelligibility has typically been measured.

Speech intelligibility has been defined as the information that a listener can recover from the speech signal (Kent, 1988), that allows the exchange and transfer of information (Yorkston & Beukelman, 1978). Impaired speech intelligibility is the prime consideration in definitions of dysarthria (Wertz & Rosenbek, 1992). Dysarthria is a collective name for a group of related speech disorders that are due to disturbances in muscular control of the speech mechanism resulting from impairment of any of the basic motor processes involved in the execution of speech (Darley, Aronson & Brown, 1975). These disturbances in muscular control result in distorted speech production. Connolly (1986) characterized intelligibility

as part of a broader perspective of determinability that involves three issues affecting communicative success: intelligibility, linguistic ambiguity and illusiveness. Of the three, intelligibility was considered to be the most serious form of communicative failure. An utterance was defined as being indeterminable "if the listener is unable to recover correctly the intended cognitive meaning of an utterance" (Connolly, 1986, p. 372).

Methods to assess intelligibility of dysarthric speech have been described and quantified by a number of authors (Beukelman & Yorkston, 1980; Darley, Aronson & Brown, 1969a,b; Platt, Andrews, Young & Neilson, 1978; Platt, Andrews, Young & Quinn, 1980; Tikofsky, 1970; Yorkston & Beukelman, 1978, 1983; Yorkston, Beukelman & Bell, 1988). Perceptual measures of speech intelligibility are used also as indices of severity. When assessing the severity of involvement in phonologically disordered children, Shriberg and Kwiatkowski (1982) investigated five variables (language measure, percentage of consonants correct, percentage of intelligible words, suprasegmental rating, and age). Of these, intelligibility was ranked as the most important variable in identifying severity of involvement.

Intelligibility scores are typically derived from tasks in which the message produced by the speaker is judged in some way by the listener. Methods generally involve either scaling techniques, using direct magnitude estimation or interval scaling, or identification tasks (Kent, Weismer, Kent & Rosenbek, 1989). When using direct magnitude estimation, the listener assigns to each stimulus a number representing the ratio of that stimulus to a standard that is either specified by the examiner or selected by the listener. In interval scaling, the listener assigns to each stimulus a number that represents a linear partition of a scale. Darley, Aronson & Brown, (1969a) rated speech samples on a seven-point equally appearing intervals scale of severity, where one represented normal speech and seven represented very severe deviation from normal. Scaling methods are useful in providing a quick, overall index of a speaker's intelligibility but are less reliable than identification tasks when repeated over time or across judges (Yorkston & Beukelman, 1978, 1980, 1983). If the clinician is the sole source of scaling data, judgements of speech intelligibility may be biased by increased familiarity with the speaker's speech patterns and by an unconscious desire to record improvement, or lack of it, on the part of the clinician (Kent, 1988).

A diagnostic phonetic intelligibility test has been developed by Kent, Weismer, Kent and Rosenbek (1989) to identify impaired speech dimensions that are contributing to reduced intelligibility. This test was designed to provide guidance in planning management and treatment programs. A multiple choice single-word format is used to analyze phonetic contrasts that are considered to be important dimensions of intelligibility and sensitive to features typically impaired in dysarthric speakers. An alternative paired-word format is provided for speakers

with severe dysarthria who would be unable to produce the more complex word shapes used in the multiple choice format.

Intelligibility has also been measured by the percentage of words that are identified correctly by a listener. The Assessment of Intelligibility of Dysarthric Speech, (AIDS) (Yorkston & Beukelman, 1981) is an example of such an assessment procedure. The scores obtained can be used to provide an index of severity, rank order speakers by severity, and to monitor changes in performance over time. When using an identification method, the speaker is typically required to read aloud a list of words or sentences, or a passage of continuous text, all of which are tasks that do not mirror everyday conversation. The listener may repeat back, select from a multiple choice array, or transcribe orthographically the words or sentences they perceive. Giolas and Epstein (1963) found that word list scores did not accurately predict continuous speech intelligibility scores. Hirsh (1952) advised that continuous discourse was more representative of speech encountered in everyday situations and hence the most logical speech message to use in intelligibility testing. Although samples of continuous spoken discourse have appealing relevance for measuring intelligibility, they may be beyond the physical capabilities of severely impaired speakers. A word-level task provides a compromise that allows the clinician to analyze speech production using a task within the speaker's abilities.

In summary, the objective in assessing the intelligibility of severely dysarthric speakers is to identify what information a listener can recover from the distorted speech signal, using procedures that are appropriate for the severity of the dysarthria and the specific clinical questions to be answered. A single word identification task appears to be the current procedure of choice for assessing the intelligibility of severely dysarthric speakers.

2.1.2 Variables Influencing the Judgement of Speech Intelligibility. This section examines four variables that affect judgements of speech intelligibility: (a) familiarity of the listener with the speaker and test materials, (b) format of test materials, (c) method of judging by listeners, and (d) method of message transmission.

Intelligibility is a relative rather than an absolute concept. The ability of a listener to understand any speaker varies according to factors such as whether the listener is aware of the topic of conversation, whether he is familiar with the speaker's voice (Brodkey 1972), his accent or dialect (Black & Tolhurst, 1955), the predictability of the semantic context, the number of sounds in error, the consistency of errors, and the frequency of occurrence of the error sound in the language. This view is supported by Flanagan (1972) and Kent et al. (1989). Kent et al. (1989) stated that an intelligibility score must be evaluated relative to the specific conditions under which the data were collected. An intelligibility score

should not be viewed as an absolute quantity (Flanagan, 1972) but rather as a function of such parameters as personnel, test material, training and test procedures. To posit an exact percentage of intelligibility is not meaningful unless considered in light of such conditions as the listener's familiarity with the speaker, the severity of the speaker, message form and content, and the communicative environment. Accordingly, it is not surprising that varying intelligibility scores may be obtained for the same speaker when different materials are rated by different listeners. Support for this notion has been reported by Monson (1983) in his work on speech intelligibility in the hearing impaired population. Monson noted that, on average, the effects of listener familiarity with the speech patterns of deaf persons increased scores on a speech intelligibility rating by 10% across all subjects and listeners, with a range of 14% for less intelligible speakers to 5% for more intelligible speakers.

Beukelman and Yorkston (1980) reported that listeners' knowledge of the speech sample influenced speech intelligibility scores for moderately severe dysarthric speakers. Scores were higher when speech-language pathologists were making judgements based on familiar standard words and passages compared with judges who were unfamiliar with the words and passages. Yorkston and Beukelman (1978) identified an interaction between the severity of dysarthria and utterance length (sentences versus words) on intelligibility scores. Less intelligible speakers received higher scores when speaking single words rather than complete sentences, while more intelligible speakers received higher scores for sentences than single words. When all other factors were held constant, sentence intelligibility scores were typically higher than single word scores, except for severely dysarthric speakers. The authors hypothesized that a short phrase or single word may facilitate a listener's ability to process phonemic cues spoken by severely dysarthric speakers because these short utterances are less demanding on the listener's processing capabilities. This finding underlines the need to identify appropriate methods of assessment for the most severely disordered speakers to determine the nature of spoken information that they can transmit.

Yorkston and Beukelman (1981) stated that a single word test with either multiple choice or transcription format is appropriate for severely dysarthric speakers. The multiple choice format was preferred for measuring subtle changes in an individual's speech over time but did not provide a valid measure of severity level. The transcription format was used to make comparisons among speakers' performances and to assign a functional level of severity.

Another variable influencing intelligibility measures is the message transmission system. Research with dysarthric speakers is typically conducted using audio recordings made and played back under optimal conditions. This is done to control for environmental variables affecting intelligibility such as background noise, lighting, and the listener's ability to "read" facial expressions,

gestures and eye gaze and so enhance spoken messages, that may occur during live or video recordings. In the natural setting listeners are aided by situational context and are not asked to understand a series of unrelated words. Moreover, in a conversational situation, dysarthric speakers can resolve communication breakdown by such strategies as repeating or changing the misunderstood message. This is not possible using available standardized testing procedures with the result that such tests may underestimate a speaker's functional intelligibility in natural speaking situations.

To summarize, variables that can potentially influence intelligibility scores when making clinical judgements include:

(a) familiarity of the judge with the message spoken and with the dysarthric speaker,

(b) format of test material (message length and linguistic complexity),

(c) method of judging responses (scaling or word identification - transcription, multiple choice selection or sentence completion), and

(d) method of message transmission (live, video or audio-recorded samples).

To be sensitive to differences among severely dysarthric speakers, the recommended procedure for obtaining perceptual ratings of speech intelligibility is to have speakers produce single words. The most common procedure used to control for factors affecting speech intelligibility is to present words by audio recording for identification by listeners who are unfamiliar with the speaker or the subject matter of the spoken material and who use a transcription response format (Yorkston & Beukelman, 1981).

2.2 Relationship Between Speech Error Patterns and Speech Intelligibility

Tests based on word and sentence intelligibility tasks, such as the Assessment of Intelligibility of Dysarthric Speech (Yorkston & Beukelman, 1981) provide a standardized means of obtaining an intelligibility severity index, but were not designed to describe or explain the speech impairment. A component-by-component analysis, such as the point-place system (Netsell & Daniel, 1979) may be used to determine the hierarchy of physiological contributors to an intelligibility deficit secondary to dysarthria. Such information regarding impairment in the speech subsystems (respiratory, laryngeal, velopharyngeal, and oral articulatory subsystems) supports information on individual speech characteristics obtained

from traditional articulation testing. Weismer, Kent, Hodge, and Martin (1988) and Kent et al. (1989) reported on work which is in progress to develop a predictive, explanatory intelligibility test. This test is based on word sets that contrast 19 different phonetic features that are typically disturbed in dysarthria. The features relate to voicing, velopharyngeal valving, and articulatory accuracy. The authors hypothesize that the nature of speech intelligibility deficits can be predicted from knowledge of the phonetic and related acoustic deficits associated with dysarthria.

Other attempts to relate speech characteristics to overall speech intelligibility have used perceptual analysis of dysarthric speech (Hixon & Hardy, 1964; Platt, Andrews & Howie, 1980; Platt, Andrews, Young & Neilson, 1978; Platt, Andrews, Young & Quinn, 1980). Phonemic analysis of adults with cerebral palsy demonstrated that, generally, they were able to produce stops, nasals, glides (manner features), and bilabials and velars (place features). Fricatives and affricates were often incorrect and devoiced, and speech sounds involving the tongue tip were reported to be deficient. Andrews, Platt and Young (1977) identified these features as being characteristic of dysarthria:

(a) anterior lingual place inaccuracy,

(b) reduced precision of fricative and affricate features, and

(c) an inability to achieve extreme positions in vowel articulatory space.

Stable features were reported from childhood to adulthood and profiles of child and adult features were noted to be similar across place and manner features.

Support for the findings of Andrews, Platt and Young (1977) was provided by Ansel and Kent (1992). They compared acoustic features of speech in a contrast word task using perceptual judgements of word intelligibility for men with cerebral palsy. Seven phonemic contrasts were examined: voiced/voiceless initial consonants, voiced/voiceless final consonants, stops/nasals, fricatives/affricates, front/back vowels, high/low vowels, tense/lax vowels. Results identified four aspects of speech as being responsible for the majority (62.6%) of variance in intelligibility scores: fricative/affricate contrasts and three vowel contrasts - front/back, high/low, tense/lax. Ansel and Kent concluded that temporal control and tongue positioning may be predictive of speech intelligibility. Kent, Netsell and Bauer (1975) observed inappropriate tongue position, abnormalities in timing and range of velopharyngeal movements, and prolonged articulatory transition times in dysarthric subjects. Re-analysis of the work of Platt, Andrews and Howie (1980) by Kent et al. (1989) identified some common phonological patterns in the speech of the dysarthric subjects: stopping, devoicing, voicing, place alterations,

fronting (word initial only), and delabialization (word final only). Favoured substitutions were these consonants: /f, m, g, s, b, k, d/ in word initial position; /t, f, n, d, k, p/ in word final position.

Kent et al. (1989) analyzed the phonetic features of speakers with dysarthria secondary to amyotrophic lateral sclerosis. They reported that as the severity of dysarthria increased, all phonetic features were affected to some degree. The most vulnerable were articulatory features associated with velopharyngeal and laryngeal functioning.

Yorkston, Beukelman and Honsinger (1989) identified four articulatory error patterns resulting from velopharyngeal insufficiency in dysarthric speakers:

(a) inability to accurately produce speech sounds requiring buildup of intraoral air pressure /p, b, t, s, t /,

(b) nasalization of vowel production,

(c) escape of air through the nose rather than the mouth, and,

(d) ability to produce nasals and glides more accurately than pressure consonants.

It is hypothesized that dysarthric speakers with velopharyngeal incompetence may overdrive the respiratory mechanism in an attempt to build up sufficient intraoral air pressure. Maximum effort of any kind is counter-productive for dysarthric speakers and may result in temporary fluctuations in abilities and motor overflow. This tendency may result in a harsh voice quality, unnecessarily short breath groups, and oral articulatory imprecision (Yorkston, Beukelman & Bell, 1988).

Any idiosyncratic behaviour, because of its unpredictability, may contribute significantly to an individual's intelligibility deficit. Such behaviours may include unusual sound distortions as well as disturbed suprasegmental aspects of speech such as abnormal rhythm, rate, stress and intonation.

In summary, although a relationship between speech error patterns and intelligibility deficit is acknowledged, it is not yet possible to reliably predict a level of intelligibility from knowledge of speech subsystem impairments or speech production errors alone. However, given the common phonetic patterns that have been found across dysarthric individuals, when linguistic analyses are used to describe speech error patterns in dysarthric speakers, such analyses should be designed to be sensitive to the features known to be at risk for these speakers.

2.3 Compensated Intelligibility

Compensation for marginal speech intelligibility can occur via contextual factors such as listener experience, word predictability, utterance length, and listener familiarity (Ansel, McNeil, Hunker & Bless, 1983). These authors investigated communicative breakdowns in severely dysarthric speakers and found that intelligibility was dependent on listener experience and word predictability. They suggested that information about the effects of listener and contextual variables on intelligibility would provide a basis for teaching compensated intelligibility. This finding was supported by Berry and Sanders (1983) who found that dysarthric speakers and their familiar communication partners were generally unaware of variables affecting intelligibility and recommended training in the use of compensatory strategies to overcome communication breakdowns.

2.3.1 Environmental Factors that Affect Intelligibility Judgements. Aural rehabilitation teaching principles were used by Berry and Sanders (1983) to examine and manipulate environmental factors to increase the intelligibility of dysarthric speakers. The factors they identified were:

(a) Situational and contextual cues that can amplify the predictability of message content. For example, when introducing or changing a topic, the speaker can provide his own context for the sentence by verbal or non-verbal means. Contextual information also may be provided automatically, such as when a closed-context question is posed, allowing the questioner to anticipate the category of response from the speaker.

(b) Interference from background noise. Background noise masks the weaker voice signal that is typical of dysarthric speakers. When they must compete against noise, their attempts to increase loudness may result in increased distortion of speech.

(c) Lighting. Provision of adequate lighting allows the listener to get additional information from the speaker's facial expressions and gestures.

2.3.2 Information Processing Factors that Affect Speech Intelligibility Judgements. In this section, information processing theory will be examined to consider how supplemental linguistic cues that provide additional contextual information may enhance a listener's ability to recognize spoken words. Then, two types of cues, letter and semantic, will be described.

Information processing theorists have identified two major hypotheses about how verbal information is processed: (a) the multi-store model, a bottom-up or data driven model (Atkinson & Shiffrin, 1968, 1971) and (b) the levels of

processing model (Craik & Lockhart, 1972). Both models acknowledge context as being vital to the recognition and recall of information. Information is recognized or encoded based on the semantic knowledge that is already in the individuals's long term memory store. Baddeley (1978) concurred that performance on short-term tasks, including word recognition and recall, may be enhanced by previously stored semantic knowledge.

A neuropsychological model of the cognitive processes involved in information processing has been developed by Luria (1970, 1973). Luria described two ways to process information. Incoming information may be processed simultaneously to synthesize it into a form that can be viewed in its entirety as one unit. This is done by examining the relationship of individual units or words with one another to organize and categorize them into a gestalt or whole. Jarman (1980, p. 157) described simultaneous processing as "nonlinear processing such that elements of information may be compared to one another in composites or matrices". Furthermore, Jarman (1980) theorized that simultaneous processing is the cognitive operation involved in processing words paradigmatically. From a linguistic perspective, the focus is on the interrelationship of meaning between words. Phonologically, paradigmatic structure is apparent in the system of distinctive features necessary to differentiate word meaning (Luria, 1982).

The second cognitive process described by Luria is successive processing, in which one unit of information is available at a time, so that the brain must store units individually. Jarman (1980) related this cognitive operation to syntagmatic processing, and described it as "the processing of information in temporal based sequential series" (p. 157). In Luria's model, both simultaneous and successive processing are responsible for the input, recording and storing of information.

In his analysis of the complex psychological processes involved in speech comprehension or speech decoding, Luria (1982) hypothesized that the search for the context of an utterance is the initial and primary focus in comprehension. This search for the general idea of an utterance, aided by the presence of concepts, dominates the probe for meaning. Moreover, the probability with which words in a message can be predicted allows the listener to enhance the comprehension process by guessing rather than actively analyzing each word. In summary, these theoretical perspectives on information processing have repeatedly highlighted knowledge of context and word prediction as important factors in enhancing the recognition, processing and comprehension of linguistic information.

Two linguistic cues that can be used to provide additional information and thereby enhance a listener's ability to predict spoken words are described below:

(i) **Letter cues.** A supplementary linguistic strategy that has been used by

dysarthric speakers to enhance their speech intelligibility is to use first-letter or initial sound cues. It is hypothesized that such priming helps the listener to make a connection between a poorly articulated word and the target word (Radeau, Morais & Dewier, 1989). Beukelman and Yorkston (1977) investigated multiple communication techniques used by non-speaking individuals and the strategies that they developed to complement natural speech. They reported that two adult subjects could improve sentence intelligibility scores from a baseline range of 16-32% to 65-75% using first-letter cuing as a supplemental word prediction strategy. Minimal speech production requirements were needed for successful use of first-letter cuing with an alphabet board. Basic requirements that were identified to use such supplementation included: (a) the ability to achieve consistent, voluntary phonation, and (b) the ability to indicate letter selections in some way (e.g. to point to letters on a board). These authors suggested that speech treatment could then focus on other goals such as vowel differentiation or inclusion of final consonants in words. Letter cuing also increased the intelligibility of natural speech by slowing speaking rates and by providing opportunities for continued use and practice of speech. Goosens and Crain (1986) recommended that first-letter cuing should enhance single word speech intelligibility by at least 20% to be considered a worthwhile augmentation strategy. Goosens and Crain (1986) also observed that speakers displaying numerous errors of vowel production were unlikely to experience success with first-letter cuing procedures.

From an alternative perspective, letter cuing has been used successfully by clinicians to increase word retrieval in aphasic individuals (Lapointe, 1978; Pease & Goodglass, 1978; Podroza & Darley, 1977). Pease and Goodglass (1978) examined a hierarchy of cuing categories used with aphasic individuals and reported that first-letter cuing was the most effective word retrieval cue when compared with sentence completion, rhythmic and semantic cues. Wolf (1982) reported that phonological cues were most effective in facilitating word retrieval in learning disabled children across varying ages. These findings indicate a preference for phonological cues over semantic cues for these populations.

(ii) Semantic cues. In addition to phonological cues, provision of semantic context is theorized to enhance listeners' abilities to decode and comprehend spoken messages. Use of semantic cuing is described in clinical studies on word association and word retrieval deficits. Although the focus in word retrieval training is to identify strategies to assist a language disordered individual to locate a word in his own lexicon, such strategies may also help a listener predict an unintelligible word spoken by a communication partner. Theories of word association have been studied by Dinnan (1971, 1973) who suggested that successful communication in any symbolic code is dependent on learning a common, semantically-based organizational system, also referred to as paradigmatic knowledge. Dinnan reasoned that construction of information in a paradigmatic fashion, as representative of the most customary mode of response,

allowed individuals to reason and communicate in similar ways. Furthermore, coding language to different or idiosyncratic organizational patterns increased the likelihood of misunderstanding and miscommunication due to the lack of shared meaning (Dinnan, 1971).

Research into free word associations with normal subjects identified consistent differences between child and adult responses based on syntax (Brown & Berko, 1960; Ervin, 1961). Children most often made syntagmatic associations, i.e. contiguous associations of a different form class than the stimulus (e.g. bird - flying), while adult responses were most often paradigmatic, i.e., contrastive or coordinate words of the same form class as the stimulus, (e.g. hot - cold, ball - toy). Although competent adult speakers used both syntagmatic and paradigmatic types of processing, the latter was found to be the most frequent (Ervin, 1961). Word associations were thought to be established by frequency of prior exposure, and enhanced by closure contexts such as sentence or phrase completion tasks (Ervin, 1961).

Study of the processes of mnemonic involvement in encoding and organizing information provides a further perspective on how individuals learn and retrieve new information. One mnemonic strategy, described by Hagen and Stanovich (1977), is the organization of material into a superordinate system. Semantically based organization includes such categorical relations as superordinate (apple - fruit), coordinate (apple - orange), and part-whole (pip - apple). It is theorized that the clustering of information into superordinate groups facilitates retention and retrieval by reducing memory load. One conceptual model of the word retrieval process identifies two classifications in lexical operations: (a) phonological, and (b) semantic processing (Miller & Johnson-Laird, 1976; Wolf, 1982). Such a model finds support from the study of aphasic individuals. When compared with the word associations of normal individuals, responses from aphasic individuals demonstrated fairly universal patterns of lexical organization that were divided between semantic and phonological processing (Brown & McNeil, 1966; Rinnert & Whitaker, 1973). Strategies typically used to facilitate word retrieval in aphasic subjects have included: (a) phonological cues, (b) topic related or semantically related cues, (c) the provision of functional definitions, and (d) sentence completion tasks.

From a practical perspective, a dysarthric individual with limited verbal skills could not be expected to provide functional definitions or sentence completion cues to complement unintelligible spoken words regardless of whether such cues were spoken or contained on a communication board. The most efficient semantic cue would be a single word or short phrase printed on a communication board that could be easily accessed to minimize interruptions in the flow of conversation when a communication breakdown occurred.

2.4 Summary

This review of literature on speech intelligibility has revealed that many questions remain concerning the methods and conditions used to measure the intelligibility of severely dysarthric individuals. To summarize the literature pertinent to intelligibility, factors affecting intelligibility can be divided into three broad groups: (a) factors intrinsic to the speech signal, (b) extrinsic factors related to the listener and environment and (c) extrinsic factors that supplement the information contained in the speech signal to increase a listener's ability to identify the words intended by a speaker.

1. Factors intrinsic to the speech signal.

   (a) segmental - the quality and number of contrastive sounds in a speaker's repertoire,

   (b) suprasegmental - the use of rhythm, rate, stress and intonation patterns, for example, the use of syllable stress to signal single versus multisyllable utterances, and the number of syllable shapes in a speaker's repertoire,

   (c) idiosyncratic - behaviours that act as miscues, such as respiratory sounds that may interfere with speech, or unusual pauses between speech sounds that may confuse the listener's perception of word boundaries.

2. Extrinsic factors related to the listener and the environment.

   (a) listener familiarity with speaker,

   (b) listener familiarity with semantic content, and

   (c) environmental adversities.

3. Extrinsic factors that augment information processing by the listener. These are strategies based on paradigmatic structure to enhance word recognition and prediction for the listener, such as

   (a) first-letter or sound cues, and

   (b) semantic cues.

This research project attempted to keep the first and second groups of factors constant (speech signal and factors relating to the listener and the environment), while manipulating the third (information processing augmentation),

to determine its effects on the intelligibility of single words produced by three dysarthric speakers. The purpose was to provide new, clinically relevant information about the interaction between residual speech and supplemental cues on the intelligibility of speakers with severe dysarthria. Specifically, the effects of two cuing strategies on the speech intelligibility scores of three speakers with severe dysarthria were investigated. It was anticipated that no one cuing strategy would maximize intelligibility scores for all three speakers. For some individuals, a combination of cues may prove more effective (Yorkston, Dowden & Honsinger, 1988). The most effective combination will likely vary for each speaker, due to age, disorder, severity level, and conversational partner. Moreover, it was considered possible that some severely disordered speakers may be unable to benefit from supplemental linguistic cues, that is, a minimum level of speech ability may be necessary for these cues to have an enhancing effect.

In addition, it was anticipated that this study would yield information about potential management options. Gallagher (1977) reported that normally developing children are able to adapt to the needs of the listener by making semantic and acoustic changes without specific training. Limited information is available on similar behaviours in children or adults with motor speech disorders. Ansel, McNeil, Hunker and Bless (1983) investigated the verbal and acoustic adjustments made by cerebral palsied dysarthric adults when faced with communicative failure. They found no pattern in altering verbal or loudness behaviours when the speakers were faced with breakdown. They hypothesized that disordered speakers become accustomed or desensitized to communication failures and require training in speaker responsibilities to modify linguistic and other aspects of an utterance to meet the needs of their listeners.

Although the use of letter cues has been described in qualitative studies, there has been no systematic examination of a quantitative nature into the validity of this approach. Information obtained from this study may assist clinicians to examine the interplay of linguistic factors inherent in the speech signal, with supplemental linguistic cues, to determine the most promising strategies to augment the speech intelligibility for speakers with severe dysarthria and thereby reduce communication breakdowns.

2.5 Statement of Purpose

The purpose of this study was to examine the effects of two linguistic cuing strategies on the speech intelligibility scores of dysarthric speakers of varying severity. The strategies investigated were letter and semantic cuing. These strategies were expected to increase word recognition and prediction in the listener. Two independent variables, Letter and Semantic Cues, each with two levels (Absent & Present), were manipulated to determine which of the four

possible combinations of these cues (no-cues, letter cue only, semantic cue only, and letter cue plus semantic cue) resulted in the greatest increase in speech intelligibility scores. The third independent variable, Severity of Dysarthria, had three levels: Moderately Severe, Severe, and Profound. The dependent variable was the Speech Intelligibility Score, the number of words correctly transcribed of the total number of possible words. These intelligibility scores were obtained by a panel of unfamiliar listeners transcribing single word samples of 50 words from each of the three speakers for a total of 150 words.

2.6 Hypotheses

This study was designed to test five hypotheses:

1) the provision of letter cues will increase the speech intelligibility scores of severely dysarthric speakers,

2) the provision of semantic cues will increase the speech intelligibility scores of severely dysarthric speakers to a degree that is equal to or greater than that provided by letter cues,

3) a combination of letter and semantic cues will provide a significantly greater increase in the speech intelligibility scores of severely dysarthric speakers than the provision of one set of linguistic cues alone,

4) significant differences will be identified among the speech intelligibility scores for the three speaker severity levels, and

5) a minimum level of speech ability necessary for linguistic cues to increase intelligibility will be identified, that is, some speakers will not benefit from any cue condition while other speakers will.

2.7 Power Calculation

Prior to conducting the study, a power calculation was completed to determine the within cell sample size (n) needed to ensure sufficient power to correctly reject the null hypothesis when it is false (Chmura-Kraemer & Thiemann, 1987). To establish the clinical validity of the hypothesis, calculations were based on Goosens and Crain's (1986) recommendation that to make a clinically significant difference to a speaker, a cuing system should increase

intelligibility by a minimum of 20% over a no-cuing condition. First, a critical effect size (C) was estimated based on the formula reported by Chmura-Kraemer and Thiemann (1987): C = N/D, where N is the difference between control mean and experimental mean and D is the standard deviation. A standard deviation of 8.4 was reported by Yorkston and Beukelman (1980) as the average percentage point difference between test-retest variability scores for a transcription task measuring the intelligibility of single words. Thus, in this study:

$$C = 20\%/8.4\% = 2.38.$$

Using the power tables (Table E.15, p.840) in Kirk (1982), a minimum within cell sample size of 9 was identified to ensure sufficient power (where p=3, alpha=0.05, C=2.00, 1-beta=0.95) to correctly reject the null hypothesis when it is false.

CHAPTER III

METHOD

Data collection for this project involved two stages. In the first stage audio recordings were obtained from three dysarthric speakers who met the pre-specified criteria for speech disorder severity levels for the independent variable of speaker severity. These audio recordings provided the speech stimuli for the second stage of data collection. In this latter stage, words that had been pre-recorded by the dysarthric speakers were transcribed by subjects in four different cuing conditions. These transcriptions were then analyzed to determine the number of words correctly identified by each subject for the three speakers.

3.1 Procedures

3.1.1 Speaker Severity Level. Three female speakers with dysarthria were selected from referrals to an assessment centre for augmentative communication. All speakers used their natural speech as their primary means of communication. One speaker was selected from each of three severity classifications: profound, severe, and moderately-severe. Severity levels of dysarthria were determined from results of the sentence portion of the Assessment of Intelligibility of Dysarthric Speech (AIDS) (Yorkston & Beukelman, 1981). Table III-1 summarizes relevant characteristics of the three dysarthric speakers.

TABLE III-1. Dysarthric Speaker Characteristics.

Speaker	Age at Recording	Diagnosis	AIDS Sentence Intelligibility Score		Severity Level
			Mean*	S.D.	
1	25 yrs.	Cerebral Palsy (mixed)	48%	4.1	Moderately Severe
2	24 yrs.	Traumatic Brain Injury	26%	4.6	Severe
3	33 yrs.	Cerebral Palsy (mixed)	13%	1.5	Profound

*Mean of 3 listener transcriptions.

Yorkston and Beukelman (1981) reported that sentence intelligibility measures obtained by transcription are appropriate for rank ordering dysarthric speakers by severity. Word-by-word (orthographic) transcription of the AIDS

sentence test, conducted according to the test manual directions, was completed by three speech-language pathologists who routinely treat dysarthric speakers. Sentence transcriptions for each speaker were scored on two separate occasions by the investigator to ensure accuracy of the scores used to assign speakers to severity levels. The number of correctly transcribed words was divided by the total number of words transcribed to obtain an intelligibility score in percent. The mean of the three listeners' scores was computed. To be selected for this study, a speaker's mean intelligibility score obtained from the transcriptions of the three speech-language pathologists, had to fall within the specified range for one of the three severity levels.

Three severity classifications were established with a ten point difference between levels. These ranges reflected the reported dispersion of point scores for repeated administration of the AIDS sentence intelligibility test with transcription format (Yorkston & Beukelman, 1981): 83% of interjudge scores fell within a ten point range. One speaker was selected from each of three severity classifications: moderately-severe (45-55%) severe (25-35%), and profound (5-15%).

3.1.2 Speaker Phonetic Status. Two descriptive analyses were completed to provide more detailed information about the speech production characteristics of the dysarthric speakers. The first was by formal articulation testing using the Fisher-Logemann Test of Articulation Competence, (Fisher & Logemann, 1971), and the second involved adminstration of a phonetic contrast paired-word test (Kent, Weismer, Kent & Rosenbek, 1989). The speakers' performance on the two tests was analyzed by two speech-language pathologists who routinely treat speakers with dysarthria.

The Fisher-Logemann Test samples 24 singleton consonant phonemes in prevocalic, intervocalic and postvocalic positions and 22 consonant blends containing consonants /s/,/l/ and /r/. Table III-2 contains a summary of the consonants, listed by manner of articulation, that were correctly produced by each speaker. Error analysis was based on three distinctive features: voicing, place of articulation and manner. Analysis of misarticulation patterns for the three speakers revealed some consistent error patterns. The majority of manner errors included fricatives, affricates and glides. All speakers demonstrated voicing/devoicing errors on stops, fricatives and affricates. Analysis by place of articulation showed that speakers were able to produce bilabial and velar stops and nasals although distorted productions were noted for bilabial glides and fricatives. Alveolar errors occurred for all three speakers. All speakers had errors in consonant prevocalic, intervocalic and postvocalic place of articulation.

TABLE III-2. Percentage Correct Production of Consonant Manner Categories for the Three Speakers.

Speaker	Fricatives	Affricates	Glides	Nasals	Laterals	Stops
One	53%	71%	50%	80%	100%	72%
Two	12%	0%	29%	75%	100%	57%
Three	31%	0%	14%	75%	67%	43%

Speaker One demonstrated few vowel errors, limited to low front and back vowels. Speaker Two demonstrated nasalization of vowel production. Speaker Three misarticulated vowels that were high (front and back), and low (front and back). All speakers had difficulty with consonant blends.

The phonetic contrast analysis was based on the production of 48 paired-word contrasts designed to test categories of speech features that are typically compromised by dysarthria. This paired-word test was developed to be within the capabilities of severely dysarthric speakers (Kent et al., 1989). A list of these contrasts and corresponding word pairs is given in Appendix A. Three word pairs were presented in each of 16 categories. These contrast categories are listed in column one of Table III-3. Speakers were judged to be able to make the phonetic contrast if they were able to contrast at least two of the three word pairs presented. Results are presented in Table III-3. Contrasts considered to be responsible for the majority of variance in speech intelligibility scores by Ansel and Kent (1992) are signified by a star (*). They include: vowel duration (long/short), fricative/affricate, tongue height (high/low) and tongue advancement (front/back).

Results for the four contrasts identified by Ansel and Kent were consistent across the three speakers: All speakers were able to contrast tongue height (high versus low) and tongue advancement (front versus back) for vowels yet unable to contrast fricatives versus affricates and vowel duration (long versus short). Other error patterns observed in all three speakers included glide/liquid contrasts and cluster/intrustive vowel contrasts. Overall, Speaker One was able to produce more word pair contrasts, correctly contrasting 63% (10/16) of the word pairs, while Speakers Two and Three were each able to correctly contrast 42% (7/16) of the word pairs.

Table III-3. Paired Word Intelligibility Test Results for the Three Speakers, Listed by Phonetic Contrast.

Contrast	Speaker One	Speaker Two	Speaker Three
Voiced/Voiceless, Word Initial	+	-	-
Voiced/Voiceless, Word Final	+	-	-
Vowel Duration, long/short*	-	-	-
Stop/Fricative	-	+	-
Glottal/Null	-	+	+
Fricative/Affric-ate*	-	-	-
Stop/Nasal	+	+	+
Alveolar/Palatal	+	-	-
Tongue Height, high/low*	+	+	+
Tongue Advancement front/back*	+	+	+
Stop/Place, labial/alveolar labial/velar alveolar/velar	+	+	+
Diphthong	+	-	+
Liquid Place	+	+	+
Glide/Liquid	-	-	-
Liquid/Vowel	+	-	-
Cluster/Intrusive Vowel	-	-	-

3.1.3 Audio Recordings.

(a) Phonetic Analysis and Sentence Intelligibility Tasks. Audio recordings of the three speakers were made in a quiet clinic room, using a Sony cassette deck (Model TC-RX410) and head-mounted microphone (Shure Model SM10A). Mouth-to-microphone distance was kept constant throughout the recordings. To retain the speakers' natural variations in loudness, recording levels were set to ensure that the peak level meter readings were in the mid-range (-3 to 0dB) during a practice counting and conversation task prior to the other tasks and then left at that level for the remainder of the recording session.

(b) Single Word Task (Audio Signal for Experimental Cuing Conditions). Difficulties were experienced in obtaining consistent, high quality recordings of the single words due to the severe nature of the speakers' disabilities. After investigating various recording conditions available in the clinical setting, (keeping the recording equipment constant), the most satisfactory conditions for recording the single words were judged to be as follows. Recording took place in a sound booth accessible to wheelchairs. Speakers One and Two used a head-mounted electret condenser microphone (Sony ECM-144). Due to Speaker Three's random head movements, the electret microphone was placed at the speaker's lapel level. Speaker Three was coached to speak when her head was in an upright, forward-pointing position in order to maintain a consistent mouth-to-microphone distance of between 6" - 8" when speaking. Recording levels were adjusted for each speaker to ensure that the majority of readings from the peak level meter fell in the optimal range. It was observed that voice intensity varied with speaking tasks so that higher recording levels were required for all speakers during single-word tasks compared with connected speech. Each speaker required coaching in different aspects of the speaking tasks. Speaker One experienced constant saliva build-up and was encouraged to halt the recording session as needed in order to swallow. Speaker Two found speaking to be effortful; her speaking rate was slow, with limited pitch and loudness variations. Velopharyngeal insufficiency resulted in audible escape of air through the nose. Speaker Three experienced difficulty in controlling loudness, with bursts of sound resulting in peak level meter readings in the high range (+3 to +6) for some word productions. In an effort to reduce the variable effects of these speaking difficulties on the quality of speech recording, each speaker's productions of the list of experimental words was recorded twice, and short breaks were provided after each set of ten words. Each speaker was encouraged to set her own pace for the speaking tasks at a comfortable speaking rate. The recording level was finalized at the beginning of the second repetition of the word list and was left at that level for the remainder of the recording session. The second recording of the list of words was used to create the master recording of the word stimuli. These procedures were instituted to balance the need for obtaining representative speaking samples with the requirement for obtaining the highest possible recording quality under challenging

recording conditions.

3.2 Subjects

Forty listener-judges with English as their first language and hearing levels within normal limits were selected from professional staff at a regional rehabilitation hospital to serve as subjects. They typically worked with physically and/or communicatively impaired individuals. All subjects were familiar with individuals who have speaking difficulties affecting intelligibility. Prior to their acceptance as subjects, they were asked to complete a questionnaire that included self-assessment of hearing and vision difficulties. If hearing concerns were identified, applicants were required to pass a hearing screening test. Hearing screening using pure tone stimuli presented at 20dB HL (re: ANSI S3.6-1969) at frequencies of 1, 2, and 4 kHz (ASHA, 1985) were completed using a portable Beltone audiometer (Model 9D) to ensure that subjects had hearing levels within normal limits. Four subjects identified possible hearing difficulties but passed the hearing screening test. No vision concerns were reported. Subjects were categorized according to speech-language pathologists versus other professional groups and then assigned randomly to one of four experimental groups each with n=10. The composition of each experimental group was as follows: 70% (7) speech-language pathologists, 30% (3) other professional groups (occupational therapy, education, audiology, physical therapy, rehabilitation engineering, & nursing). The ages of subjects fell within these ranges: 26% were under age 30, and 74% were between 31 and 45 years. Ten percent of the subjects were male and 90% were female.

3.2.1 Informed Consent. The parameters of the study and the extent of involvement were explained verbally to each speaker and subject. Speakers and subjects received a written description of the study and signed a consent form indicating their willingness to participate in the study.

3.3 Preparation of Stimuli for the Experimental (Cue) Conditions

The procedures described in the Assessment of Intelligibility of Dysarthric Speech (Yorkston & Beukelman, 1981) were used to obtain three unique tests each with fifty single words. Yorkston and Beukelman (1981) investigated the equivalency of randomly generated word lists and reported that sample differences contributed minimally to test-retest variability. Pearson product-moment correlation r-values of 0.994 were reported by Yorkston and Beukelman (1981) when different AIDS single word lists, recorded by the same speaker, were analyzed. Each 50-word sample was assigned to one of the three dysarthric speakers and their productions of these words were audio recorded using the

procedures described previously. These word recordings were used to prepare a master listening tape containing all 150 words, randomized across the three subjects. This tape was prepared in the following manner. Each word recording was digitized using a computer speech waveform acquisition, editing and analysis program (Milenkovic, 1989) to create 150 separate word files. A Soroc 386 computer and Data Translation DT 2821 data acquisition card were used. A sampling rate of 22 kHz with a 12 bit quantization size was used to digitally record the words using a Butterworth low pass input filter (Frequency Devices, Model 901FI) set at 9.5 kHz. The 150 word files were randomized into a sequence with each word separated from the next by an 8-second interval. The randomized sequence of the 150 word files was played back through a Butterworth low pass output filter (Frequency Devices, Model 901F1) set at 9.0 kHz. The filtered file sequence was recorded on a Sony audio cassette recorder (Model RX410) to generate an analog master stimulus tape. The analog master tape was duplicated on four video tapes with each tape representing one of four listening (cue) conditions, as follows:

1) audio cues only as produced by the speakers, with no supplemental linguistic cues (no-cue condition or NC),

2) audio cues supplemented with simultaneous letter cues provided by video signal, (letter cue condition or LC),

3) audio cues supplemented with simultaneous semantic cues provided by video signal, (semantic cue condition or SC), and

4) audio cues supplemented with both a letter and a semantic cue provided simultaneously by video signal (letter and semantic cue condition or L&SC).

3.4 Preparation of Linguistic Cues

The 150 stimulus words and the corresponding semantic cues are provided in Appendix B, divided into three sets of 50 words produced by each speaker. Semantic cues were selected to provide paradigmatic information by using grammatical class categories. Printed words identified the grammatical category of the spoken word as verbs, descriptors, conjunctions, prepositions and nouns. The grammatical category of nouns was further subdivided to provide superordinate labels to group individual nouns into common categories (animals, body parts, buildings, clothing, containers, emotions, food, fuel, hobbies, household items, miscellaneous, names, outside places, people, plants, pronouns, school items, shapes, tools, transportation, utensils, weapons, weather, & work items). Category labels for nouns were selected by the investigator according to an association with

the noun's primary meaning reported in the Standard College Dictionary, Canadian Edition (Funk & Wagnalls, 1983) and confirmed by two speech-language pathologists. Many nouns, particularly those that are obscure or abstract, could not be categorized (e.g. "law" and "form") and were pooled in a "miscellaneous" group. Some words fell in both noun and verb classes. Assignment of such words to a grammatical category was determined by selecting the most frequent grammatical classes reported in the Standard College Dictionary, Canadian Edition, (Funk & Wagnalls, 1983), which was based on the frequencies reported in the Thorndike and Lorge (1944) word list. A summary of the frequency of occurrence of each grammatical category for the three speakers' word lists is given in Appendix B, Table VIII-1.

The category labels for nouns used in this study were selected to represent the categories appropriate for the master word list and not to be representative of categories for typical conversational usage. For speakers who benefit from the use of this cuing strategy, semantic cue sheets could be designed to contain categories relevant to topics of interest to the individual user and would vary from user to user.

3.5 Data Collection

Ten subjects were randomly assigned to transcribe the 150 word productions in each of four listening conditions (N=40). An eight second interval between words allowed time for transcribing the words. A break of one minute was provided after every 25 words. The subjects in the no-cue condition transcribed each word in the 150 word corpus with only the word number displayed on the video playback monitor. The remaining three groups of subjects heard the words simultaneously with the presentation of printed letters representing letter and/or semantic cues via a video signal on a playback unit consisting of a Panasonic monitor (PC 21554R), monitor screen size 20", and Panasonic recorder (PU 4002K0). In all conditions the audio output of the VCR was connected to an external amplifier (Sony Integrated Amplifier TA AY 320) and external speaker (Sony Model APM 550AV) while supplemental linguistic cues were presented via the video playback.

Immediately prior to the transcription task, all subjects completed a training session. During the training session all subjects were asked to read the complete AIDS master word list (600 words) twice to familiarize themselves with the words. Subjects for the two conditions with semantic cues were also given the list of possible semantic cues and instructed to read these over twice. To prepare the subjects for the severity level of the speakers, all subjects listened to an audio tape containing five sentences spoken by a severely dysarthric speaker, who was not one of the three experimental speakers. Subjects were then asked to

transcribe recordings of six practice words (two for each dysarthric speaker) that had been selected randomly from the AIDS master word list, excluding the words on the experimental word list. Cues were provided in accordance with the subject's cue condition (no cues, first-letter cues, semantic cues, or first-letter and semantic cues). These practice words were not scored and the subjects were not provided with feedback about the accuracy of their word transcriptions.

All experimental listening sessions were conducted in a sound booth with the audio/video taped samples presented in sound field. The distance between subjects and audio speakers was four to six feet. Recordings were played at a comfortable listening level as determined by the subjects. Subjects heard each word only once and then transcribed (orthographic) their response. Each subject transcribed all 150 words, (50 words from each of the three speakers). At the end of the session, the transcription sheets were returned to the investigator who calculated the intelligibility score for each subject's responses. The total number of words correctly transcribed for each of the three speakers was calculated (total possible = 50).

3.6 Scoring Reliability

To ensure accuracy of the single word test transcription scores (dependent variable), the investigator scored all subjects' transcriptions twice. To establish accuracy across judges in scoring the word transcriptions, interjudge reliability of these scores was established by having a speech-language pathologist familiar with the AIDS test rescore a random selection of 10% of the words in the corpus. The transcription sheets of four subjects were randomly selected from each of the four groups. Using these procedures there was 100% agreement between judges for the transcription scores.

3.7 Data Analysis

A three factor (2x2x3) mixed design was used to test the experimental hypotheses. Equality of variances across the four cuing conditions was established by completing an F-maximum test for homogeneity of variances (Bruning & Kintz, 1987). A three-way analysis of variance was performed using Letter Cues (present/absent), Semantic Cues (present/absent) and Speaker Severity Level (profound/severe/moderately severe) as independent variables and Speech Intelligibility Scores as the dependent variable. When statistically significant results were obtained for main and interaction effects, post hoc analyses were completed to determine where significant differences occurred.

CHAPTER IV

RESULTS

An F-maximum test for homogeneity of variances among independent groups was conducted (Bruning & Kintz, 1987) and yielded an F-maximum ratio of 3.46. This was below the critical value of 6.31 (4 variances, df=9, p=0.05) so these results were interpreted to mean that the four variances could be considered homogenous. A three-way analysis of variance (ANOVA) was completed to determine the effects of Letter Cues (present/absent), Semantic Cues (present/absent), and Speaker Severity Level (profound/severe/moderately severe) on the number of words correctly identified by listeners.

4.1 Main Effects

The source table for the ANOVA (Table IV-1), shows that significant main effects were obtained for all three independent variables (Letter Cue, Semantic Cue & Speaker Severity). The addition of letter cues significantly increased single word intelligibility scores, as did the addition of semantic cues. Significant differences for Speaker Severity were revealed.

Figures IV-1 through IV-3 provide comparisons of the results by cue condition and by speaker. The mean speech intelligibility scores obtained under the four cuing conditions are shown in Figure IV-1. The greatest increase in speech intelligibility scores was achieved when letter and semantic cues were combined (mean = 12.5 words). Letter cues showed a similar increase to semantic cues. The scores for both of these cues used in isolation were greater than for the no-cue condition, but less than the increase achieved in the combined cue condition. Table IV-2 contains the group mean intelligibility scores and standard deviations for each cuing condition.

TABLE IV-1. Source Table: Three-Way Analysis of Variance.

Source	SS	df	ms	F	p
Letter Cue (LC)	607.5	1	607.5	68.4	.0001*
Semantic Cue (SC)	672.1	1	672.1	75.7	.0001*
Severity Level (SL)	1744.8	2	872.4	169.2	.0001*
Subjects w.groups	319.4	36	8.8		
LC x SC	7.5	1	7.5	0.8	.3640
LC x SL	20.1	2	10.0	1.9	.1491
SC x SL	72.2	2	36.1	7.0	.0017*
LC x SC x SL	40.9	2	20.4	3.9	.0231*
SL x Subjects w.groups	371.2	72	5.1		

*significant results when $p \leq 0.05$

Figure IV-2 provides a further breakdown of the speech intelligibility scores by speaker for each of the four cuing conditions. Speech intelligibility scores increased for subjects listening to all speakers when linguistic cues were provided compared with the no cue condition. Letter and semantic cues combined to provide the greatest increase in speech intelligibility scores over the single linguistic cue and no cue conditions for all speakers.

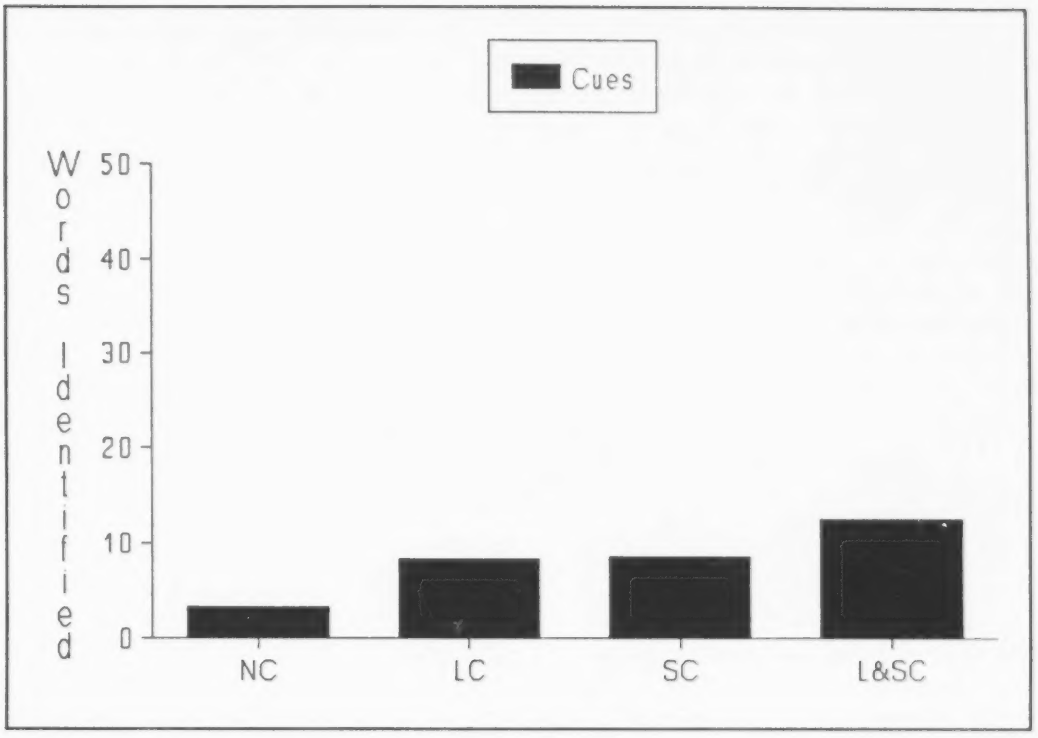

FIGURE IV-1. Mean Speech Intelligibility Scores by Cuing Conditions, All Speakers Combined.

TABLE IV-2. Group Mean Speech Intelligibility Scores and Standard Deviations for Each Cuing Condition (Averaged Across All Speakers).

Condition	Mean Intelligibility Score	Standard Deviation
No cue	3.3	1.6
Letter cue	8.3	3.3
Semantic cue	8.5	2.1
Letter & Semantic cue	12.5	2.4

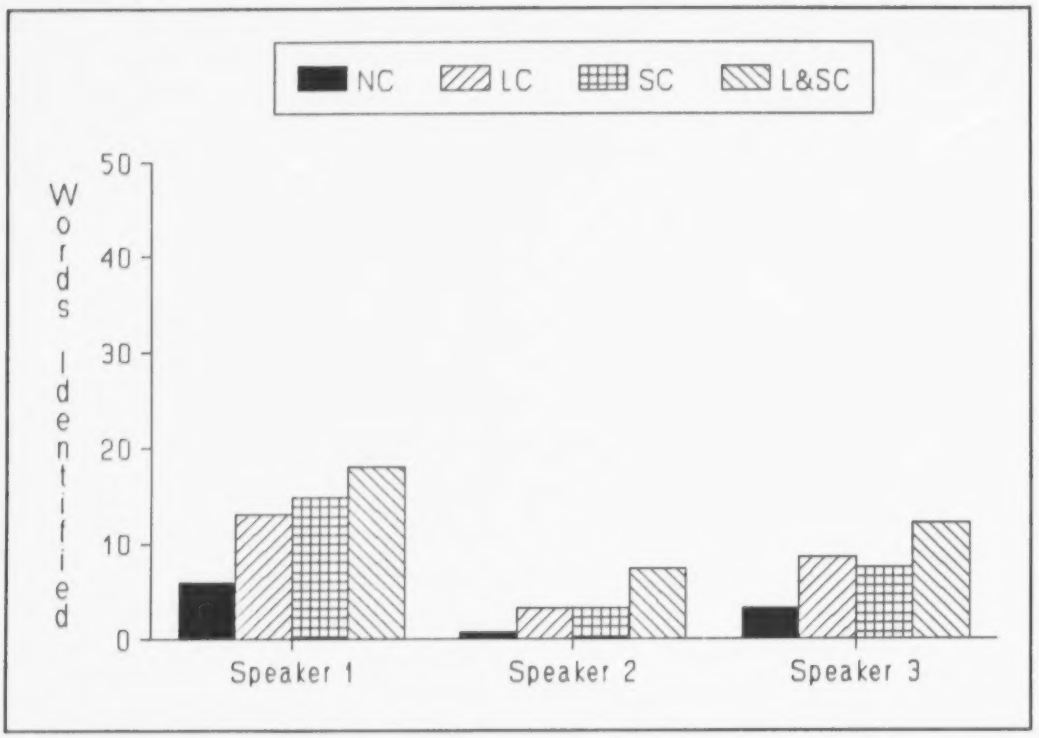

FIGURE IV-2. Mean Speech Intelligibility Scores by Speaker for Each Cuing Condition.

Mean speech intelligibility scores and standard deviations for each cuing conditions for the three speakers are summarized in Table IV-3.

TABLE IV-3. Mean Speech Intelligibility Scores and Standard Deviations for Each Cuing Condition, by Speaker.

Speaker	No Cue		Letter Cue		Semantic Cue		Letter & Semantic Cue	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
One	5.9	2.8	13.1	3.8	14.8	2.5	18.0	3.1
Two	0.7	0.7	3.2	2.6	3.2	2.0	7.4	1.6
Three	3.2	1.1	8.5	3.6	7.5	1.8	12.1	2.5

4.1.1 Post Hoc Analysis on Speaker Severity. A Scheffe F-test was conducted to examine the differences among the three speakers. The results of the post hoc analysis are shown in Table IV-4. Significant differences in intelligibility scores occurred with each speaker differing significantly from the other two. As shown in Table IV-3, Speaker One had the greatest intelligibility scores in all cue conditions, while Speaker Two had the lowest intelligibility scores in all cue conditions.

TABLE IV-4. Scheffe F-Test Results for Speaker Severity.

Speaker 1 vs. Speaker 3	F= 40.608*
Speaker 1 vs. Speaker 2	F= 134.436*
Speaker 2 vs. Speaker 3	F= 27.272*

*significant when $p \leq 0.05$

4.2 First-Order Interactions

There was no significant interaction between letter cue and semantic cue. Thus, the combination of letter cue and semantic cue did not significantly increase intelligibility scores beyond the increase obtained by each cue in isolation.

The interaction between Letter Cue and Speaker Severity was determined by comparing the mean scores for the two letter cue present conditions (that is, letter cue alone plus letter combined with semantic cue) with the mean scores for the two letter cue absent conditions (that is, no cue plus semantic cue alone). The interaction between Letter Cue and Speaker Severity was not significant. Thus, the addition of letter cues had a similar effect across the three speaker severity levels. Mean speech intelligibility scores by speaker for letter cue present and absent, (Table IV-5), show that scores increased for all speakers when letter cues were added compared with no letter cues. With the addition of letter cues, intelligibility scores for Speaker One increased by 5.2, while scores for Speaker Two increased by 3.35 and by 4.95 for Speaker Three.

TABLE IV-5. Mean Speech Intelligibility Scores for Speakers when Letter Cues were Absent/Present.

Letter Cue	Speaker One	Speaker Two	Speaker Three
Absent	10.35	1.95	5.35
Present	15.55	5.30	10.30

In addition to the significant main effect obtained for Semantic Cue, there was a significant first-order interaction between Semantic Cue and Speaker Severity Level. This is illustrated in Figure IV-3. The mean intelligibility scores are listed in Table IV-6.

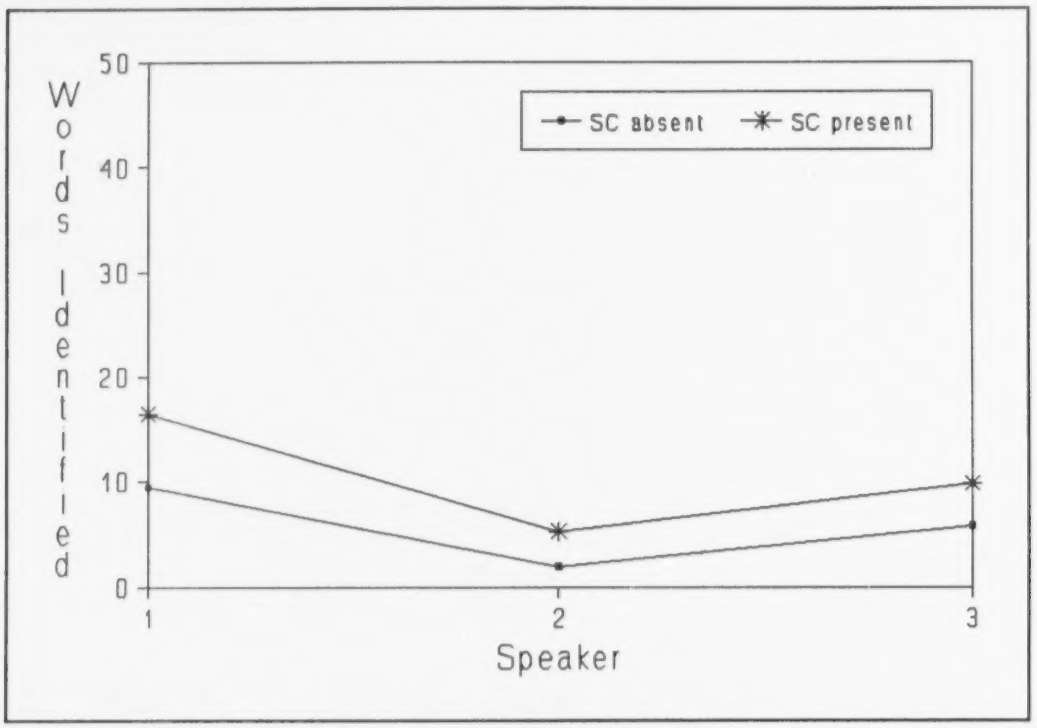

FIGURE IV-3. Mean Speech Intelligibility Scores Showing Interaction Between Speaker Severity and Semantic Cue (Present/Absent).

The interaction between semantic cue and speaker severity was determined by comparing the mean scores for the semantic cue present conditions (that is, semantic cue alone plus semantic combined with word cue) and the mean scores for the semantic cue absent conditions (that is, no cue plus letter cue alone).

TABLE IV-6. Mean Speech Intelligibility Scores for Speakers when Semantic Cues were Absent/Present.

Semantic Cue	Speaker One	Speaker Two	Speaker Three
Absent	9.50	1.95	5.85
Present	16.40	5.30	9.80

4.2.1 Post Hoc Analysis on First-Order Interaction (Semantic Cue by Severity Level). A simple-effects test revealed that Speakers One, Two and Three differed significantly when subjects were provided with semantic cues. The results of the simple-effects test are summarized in Table IV-8. Using semantic cues, Speaker One showed the greatest increase in words identified (6.9) while Speaker Two showed the smallest increase (3.35).

TABLE IV-7. Differences by Speaker for the Effects of Semantic Cues.

Speaker 1 vs. Speaker 3	F = 4.3*
Speaker 1 vs. Speaker 2	F = 11.6*
Speaker 2 vs. Speaker 3	F = 7.3*

*significant when $p \leq 0.05$

4.3 Second-Order Interaction

There was a significant second-order interaction among Letter Cue and Semantic Cue when Speaker Severity was added. This result is illustrated in Figure IV-4.

The mean intelligibility scores and standard deviations for the combined condition are listed in Table IV-3 for each speaker.

4.3.1 Post Hoc Analysis on Second-Order Interaction. Simple-simple effects tests were completed to determine the most significant cuing conditions for each speaker.

(a) Speaker One. A two-way ANOVA was completed to identify the most effective cuing condition for subjects listening to Speaker One. The source table for the analysis of variance is shown in Table IV-8. Significant results were obtained for Letter Cue, Semantic Cue, and Letter and Semantic Cues combined.

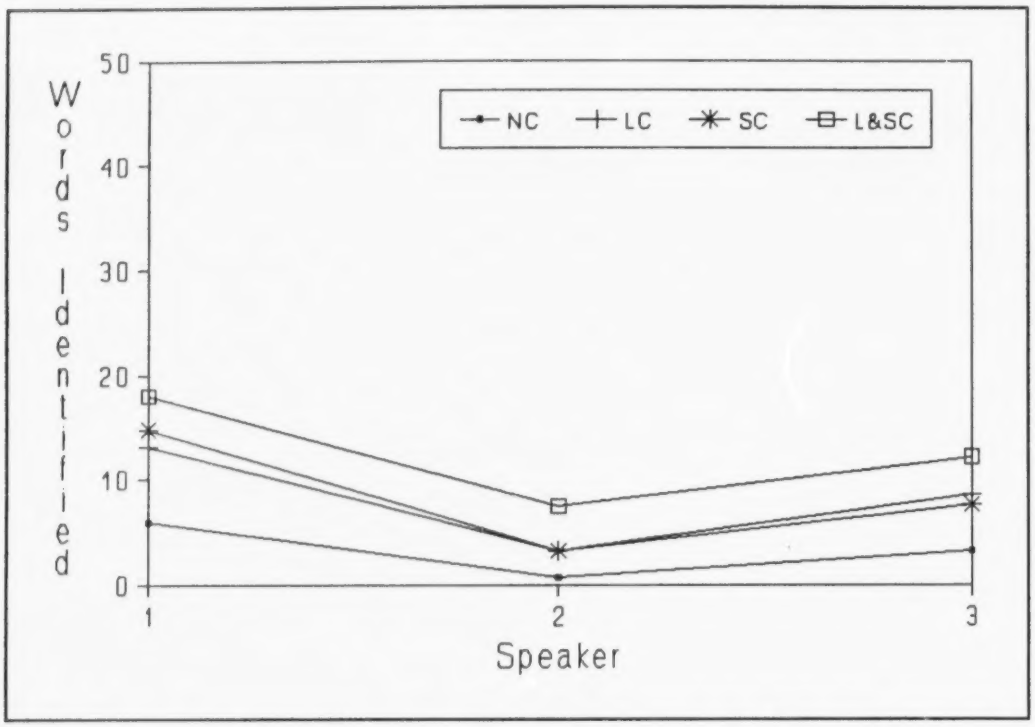

FIGURE IV-4. Mean Speech Intelligibility Scores Showing Interaction Among Letter Cue, Semantic Cue and Speaker Severity.

TABLE IV-8. Source Table: Two-Way ANOVA on Speech Intelligibility Scores for Speaker One.

Source	SS	df	MS	F	p
LC	270.4	1	270.4	27.86	.0001*
SC	476.1	1	476.1	49.05	.0001*
LC x SC	40.0	1	40.0	4.12	.0498*
Error	349.4	36	9.7		

*significant when $p \leq 0.05$

A simple effects test revealed differences across cue conditions for Speaker One. Subjects correctly identified significantly more single words when provided with letter cues compared with no-cues. Subjects correctly identified significantly more single words when provided with semantic cues compared with no-cues. In addition, subjects correctly identified significantly more single words when

addition, subjects correctly identified significantly more single words when provided with both letter cues and semantic cues compared with no-cues. Subjects correctly identified significantly more single words when provided with both letter cues and semantic cues compared to letter cues alone.

There were no significant differences between the mean number of single words correctly identified when subjects were provided with letter cues and the mean number of single words correctly identified when subjects were provided with semantic cues. Nor was there was a significant difference between the mean number of single words correctly identified when subjects were provided with both letter cues and semantic cues and the mean number of words correctly identified when subjects were provided with semantic cues alone. Accordingly, two cuing options are appropriate for Speaker One: either semantic cues alone or in combination with letter cues.

(b) **Speaker Two.** A two-way ANOVA was completed to determine the most effective cuing conditions for subjects listening to Speaker Two. The source table for the analysis of variance is contained in Table IV-9. The results indicated that two conditions were significant for subjects listening to Speaker Two. The addition of letter cues significantly increased single word intelligibility scores. Further, the addition of semantic cues significantly increased single intelligibility scores. The combination of both letter cues and semantic cues did not significantly increase single word intelligibility scores for Speaker Two beyond that afforded by each cue in isolation.

TABLE IV-9. Source Table: Two-Way ANOVA on Speech Intelligibility Scores for Speaker Two.

Source	SS	df	MS	F	p
LC	112.2	1	112.2	32.1	.0001*
SC	112.2	1	112.2	32.1	.0001*
LC x SC	7.2	1	7.2	2.1	.1589
Error	125.7	36	3.		

*significant when $p \leq 0.05$

A simple effects test revealed that the use of either letter or semantic cues was equally effective for subjects listening to Speaker Two. There was no significant difference between the mean number of single words correctly identified when subjects were provided with letter cues and the mean number of single words correctly identified when subjects were provided with semantic cues. The effects of cuing conditions on speech intelligibility scores for Speaker Two are

illustrated in Figure IV-2.

(c) Speaker Three. A two-way ANOVA on speech intelligibility scores for subjects listening to Speaker Three revealed main effects similar to those obtained for Speaker Two. The source table for the two-way ANOVA is contained in Table IV-10. The addition of letter cues significantly increased single word intelligibility scores. Furthermore, the addition of semantic cues significantly affected single word intelligibility scores for Speaker Three. The combination of both letter cue and semantic cue did not significantly increase single word intelligibility scores for Speaker Three beyond that afforded by each cue in isolation. The effects of cuing conditions on the speech intelligibility scores for Speaker Three are illustrated in Figure IV-2.

TABLE IV-10. Source Table: Two-Way ANOVA on Speech Intelligibility Scores for Speaker Three.

Source	SS	df	MS	F	p
LC	245.0	1	245.0	40.9	.0001*
SC	156.0	1	156.0	26.1	.0001*
LC x SC	1.3	1	1.2	0.2	.6537
Error	215.5	36	5.9		

*significant when $p \leq 0.05$

A simple effects test for Speaker Three revealed results similar to those of Speaker Two. There were no significant differences between the mean number of single words correctly identified when subjects were provided with letter cues and the mean number of words correctly identified when subjects were provided with semantic cues. Hence, for Speaker Three, it appeared that the use of either letter or semantic cues would be appropriate to enhance speech intelligibility judgements.

CHAPTER V

DISCUSSION

Based on results reported by Yorkston, Beukelman and Bell (1988), it was hypothesized that the addition of letter cues would increase the ability of listeners to identify words spoken by persons with severe dysarthria. What could not be predicted was whether semantic cues alone, or in combination with letter cues, would result in a similar or greater enhancement of intelligibility scores of dysarthric speakers. Using information processing theory one would hypothesize that the addition of a semantic cue would enhance a listener's ability to identify a word produced by a dysarthric speaker (that is, increase word intelligibility scores). However, the magnitude of this effect could not be predicted. Accordingly, it was also hypothesized that the provision of semantic cues would have equal or greater positive effect on the speech intelligibility scores of severely dysarthric speakers, compared to letter cues. Third, it was hypothesized that a combination of letter and semantic cues would provide a greater increase in the speech intelligibility scores of severely dysarthric speakers than the provision of either of these linguistic cues alone. Fourth, it was also hypothesized that differences would be identified among the speech intelligibility scores for the four cuing conditions when compared across speaker severity level. Finally, it was hypothesized that a minimum level of speech ability may be required for a speaker to benefit from supplemental linguistic cues.

The results of this study corroborated previous findings indicating that letter cues assist listeners in recognizing words spoken by individuals with severe forms of dysarthria. Results also indicated that semantic cues increased the intelligibility of severely dysarthric speakers, at a magnitude similar to first-letter cuing. All listeners benefitted from the addition of linguistic cues. Although the addition of linguistic cues improved listeners' ability to understand the speakers, differences were revealed when interaction of linguistic cue with speaker severity level was examined. Semantic cues alone or in combination with letter cues provided the most efficient methods to increase intelligibility scores for Speaker One, the least severely affected speaker. For the more severely impaired speakers (Two & Three) speech intelligibility scores increased when listeners were provided with either letter cues or semantic cues. Either cuing condition provided similar increases in intelligibility scores. Moreover, no minimum level of speech ability was identified as being necessary for these cues to increase word identification scores for the speakers in this study.

The third hypothesis was not supported. It was found that combining two linguistic cues together did not similarly increase listener intelligibility scores for all speaker severity levels. Although higher scores were obtained for the combined letter and semantic cue condition for Speaker One, this increase over the semantic

cue condition alone (mean difference = 3.2 points) was not significant. The combined cuing condition did not significantly increase subjects' scores above those obtained for either linguistic cue for speakers at the severe and profound level.

Use of one cue rather than two is also preferable for pragmatic reasons. From a practical perspective, it is more efficient for a speaker to provide only as much cuing as necessary to repair a communication breakdown, thereby minimizing interruptions in conversational flow.

5.1 Clinical Significance of Results

Although statistically significant effects were obtained for all three independent variables, these results would not be considered clinically significant according to the guidelines suggested by Goosens and Crain (1986). Goosens and Crain recommended that a minimum increase of 20% (10 points) or greater in any group's intelligibility scores compared with the no-cue group would be required for the improvement to be considered clinically significant. Means, standard deviations and ranges of intelligibility scores for each cuing condition are shown in Table V-1.

TABLE V-1. Means, Standard Deviations and Ranges of Intelligibility Scores by Cuing Condition.

Condition	Mean Score	Standard Deviation	Range
NC	3.3	1.6	0 - 10
LC	8.3	3.3	1 - 18
SC	8.5	2.1	0 - 19
LC+SC	12.5	2.4	5 - 22

Differences between the means in the cued and non-cued conditions are itemized in Table V-2. None of the supplemental cuing conditions met the criterion of Goosens and Crain (1986), that is a minimum increase of 20% when compared with the no-cue condition.

TABLE V-2. Differences in Mean Intelligibility Scores Between Cuing Conditions.

Condition	Cued Mean	No-Cue Mean	Difference	Percent Change
LC - NC	8.26	3.26	5.0	10.0%
SC - NC	8.50	3.26	5.2	10.4%
(LC+SC) - NC	12.50	3.26	9.2	18.4%

Analysis of cuing condition by speaker, shown in Table V-3, revealed clinically significant differences for one speaker only when using Goosens and Crain's criterion. The combined cuing condition, (letter & semantic cues) was found to cause a clinically significant increase in intelligibility scores for Speaker One. The combined letter and semantic cue condition (LC+SC = 18.0) minus the no cue condition (NC = 5.9) equals 12.1 which, divided by the number of possible words correctly identified (50) results in a 24.2% increase. This is not consistent with the outcome of the statistical analysis of these conditions. While a second order interaction showed that the combined cue condition increased subjects' ability to identify the utterances of Speaker One, compared with the no cue and letter cue conditions alone, semantic cues alone or in combination with letter cues provided a similar degree of assistance. No clinically significant differences were obtained for listener scores for Speakers Two and Three under any of the cuing conditions (LC, SC, LC+SC) compared with the no-cue condition using Goosens and Crain's criterion.

TABLE V-3. Mean Differences in Intelligibility Scores Between Cuing Conditions for each Speaker.

Condition	Speaker One	Speaker Two	Speaker Three
NC	5.9	0.7	3.2
LC - NC	13.1 - 5.9 = 7.2 (14.2%)	3.2 - 0.7 = 2.5 (5%)	8.5 - 3.2 = 5.3 (10.6%)
SC - NC	14.8 - 5.9 = 8.9 (17.8%)	3.2 - 0.7 = 2.5 (5%)	7.5 - 3.2 = 4.3 (8.6%)
(LC+SC) - NC	18.0 - 5.9 = 12.1 (24.2%)	7.4 - 0.7 = 6.7 (13.4%)	12.1 - 3.2 = 8.9 (17.8%)

In reality, considerable enhancement of intelligibility scores was achieved for all speakers in all supplemental cue conditions. The point difference between the no-cue condition and the combined cue condition was dramatic, with a three-

fold enhancement of listener scores for Speaker One, more than a ten-fold enhancement for Speaker Two, and an almost quadrupling of scores for Speaker Three. It can be speculated that the speakers' communication effectiveness would be enhanced by increases of this magnitude on the listeners' ability to understand them. Projecting increases of this magnitude to sentence scores may further multiply the effects of the cues. Applying Goosens and Crain's guidelines may be unreasonable for speakers at this level of severity. For such severely dysarthric speakers who are using speech as their main method of communication, any strategy that enhances their speech intelligibility would be helpful.

5.2 Cuing Conditions

Based on information processing theory it was hypothesized that the additional contextual information provided by the linguistic cues would increase listeners' ability to predict the words of dysarthric speakers. It was conjectured that listeners would be able to synthesize auditory and visual elements into a gestalt. Linguistic cues were selected to provide paradigmatic knowledge in two forms. It was proposed that letter cues would provide some distinctive features to prime the listener to identify spoken words and that semantic cues would provide contextual information to assist the listener in identifying the intended word from a distorted spoken production of the word.

Listeners in all groups reported that the word identification task was difficult and that the speakers were extremely hard to understand. This is supported by the overall low range of scores for correctly identified words. The highest score obtained by any subject while listening to the most intelligible speaker was 22 words (44%) correctly identified out of a possible 50. The range of scores for the number of correctly identified words for all three speakers combined, out of a possible total of 150 words, is shown in Table V-4.

TABLE V-4. Range of Intelligibility Scores for the Four Cuing Conditions.

Group One (NC)	6 - 14
Group Two (LC)	16 - 33
Group Three (SC)	17 - 33
Group Four (LC+SC)	22 - 44
Overall Range	6 - 44

The listeners' transcripts were examined to determine whether there was a pattern to how subjects used linguistic cues to assist in word identification. This

examination revealed that 107 words (71%) were correctly identified by at least one judge in one of the four experimental conditions and 43 words (29%) were never correctly identified under any cuing condition by any of the listeners. Of the words that were not identified by any listener, the largest proportion (0.54) was produced by Speaker Two. Table V-5 summarizes the number of words per speaker that were never identified by any listener and the proportion of these to the total number of words never correctly identified.

TABLE V-5. Unidentified Words by Speaker.

Speaker	Unidentified Words	
	Number	Proportion
One	7	0.16
Two	23	0.54
Three	13	0.30
Total	43	1.00

There was no consistency across subjects or across words as to how either letter or semantic cues helped listeners to identify single words. Words were identified in random fashion, with 60% of the correctly identified words recognized by 3 or fewer subjects per group and only 16% of the correctly identified words recognized by 8 or more subjects per group. There was no obvious pattern to the effects of the cues on the listeners' ability to guess specific words.

The two listener groups that received semantic cues also commented on the difficulty of using these cues to advantage. This was confirmed by an examination of these listeners' transcriptions. They often guessed words that did not fall within the grammatical category provided for the word. Although the distorted speech signal may have misled listeners, they could depend on the accuracy of the printed cues to be more reliable than the speech signal. Yet when this mismatch occurred, listeners invariably tended to guess based on what they heard rather than what they saw. Listeners appeared to respond to the intrinsic nature of the speech signal rather than the extrinsic cue. This behaviour was not evident in the letter cue condition. In all letter cue instances listeners selected a word that started with the letter cue provided. From these results it is possible to conjecture that listeners found the letter cue easier to use than the semantic cue. Listeners were able to make use of the priming information provided by letter cues more consistently than the semantic cue information. An unexpected outcome of the study was that the combined letter and semantic cue condition did not combine to help the listener predict a significantly greater number of words.

Listeners' transcriptions for groups receiving semantic cues were also examined to identify the grammatical classes of semantic cues that were applied effectively by subjects. The percentage of words within each grammatical category and the percentage of words correctly identified within that grammatical category by any judge are summarized in Table V-6. Words assigned a noun category label were correctly identified most frequently whereas verbs were identified least frequently by listeners. The majority of incorrectly identified words fell into the category of verbs (49%), followed by descriptors (35%) and then nouns (19%), even though nouns constituted the largest class of words within the sample (56.7%), followed by verbs (26%) and then descriptors (15.3%). These results suggest that nouns were identified most easily by the listeners.

TABLE V-6. Correctly Identified Words by Semantic Category.

Category	Correctly Identified Words		Total Word Sample	
	No.	%	No.	%
Nouns	69	81	85	56.7
Verbs	20	51	39	26.0
Descriptors	15	65	23	15.3
Conjunction	2	100	2	1.3
Prepositions	1	100	1	0.7

While the percentage of words within each grammatical category is reported, it should be noted that there was no attempt made to balance the number of words within each semantic category in the three word lists.

5.3 Interaction between Severity of Dysarthria and Utterance Length

The results of this study refute Yorkston and Beukelman's (1978) conclusion that less intelligible speakers receive higher scores when speaking single words compared with sentences. Yorkston et al. (1978) found that sentence intelligibility scores were higher than single word scores for all dysarthric speakers except for those considered severely dysarthric. In this study sentence intelligibility scores were consistently higher than single word intelligibility scores obtained under the no-cue condition across all levels of speaker severity. Sentence and single word intelligibility scores for the three speakers are summarized in Table V-7.

TABLE V-7. AIDS Intelligibility Scores for Sentence and Word Tests for Each Speaker.

Speaker	Sentence Score	Word Score
One	48%	12%
Two	26%	2%
Three	13%	6%

The severity ratings created for this study were based on the reported test-retest variability for AIDS Sentence test scores (Yorkston & Beukelman, 1982). Three speaker severity categories were created (profound, severe, & moderately severe) according to the sentence scores. These categories had a ceiling of 55% and were separated by 10 points (profound 5-15, severe 25-35, moderately severe 45-55). This decision was supported by Yorkston and Beukelman's (1981) report that 83% of scores fell within a 10 point range. Yorkston and Beukelman (1981) reported that 93% of sentence test intelligibility scores fell within a 20 point range, indicating that a 10 point differentiation between levels may be too narrow. Thus, establishing a 20 point difference between categories may be more effective in differentiating between severity levels. Because scores for Speakers Two and Three fell within a 20 point range of each other, they may overlap into one severity level. A more conservative approach for future investigation would be to establish levels of speakers differentiated by a 15 point range, such as severe 5-15%, moderate 30-40%.

5.4 Ranking of Speakers

Speakers were initially ranked least to most severe (one through three) according to the results of the AIDS sentence scores. The ranking of speakers by sentence scores was not replicated by the single word task, as shown in Table V-7. The single word scores for Speaker Three, ranked lowest (in the profound range) based on sentence scores, were consistently higher compared with those for Speaker Two. Speaker Two was classified as being severe according to sentence scores, yet received consistently lower scores than Speaker Three on the single word task. Listeners experienced the most difficulty in understanding Speaker Two, with the highest proportion of unidentified words attributed to this speaker. It has been suggested that the severity classification was flawed and that Speakers Two and Three could be considered to fall within the same severity classification. Nonetheless, results for the experimental single word task identified significant differences among speakers based on severity distinctions, again reversing the placement of Speakers Two and Three. Of interest is the end result, that the

same cuing conditions were deemed appropriate for both speakers, that is from a clinical point of view their treatment options would be the same.

CHAPTER VI

CONCLUSIONS

The results of this study demonstrated that no one method of supplemental linguistic cues was found to maximize intelligibility scores for all three severely dysarthric speakers. In general, both letter and semantic cues provided a similar enhancement of listeners' ability to understand the speech of speakers with severely compromised intelligibility. Both cuing conditions were effective in increasing the identification of words by listeners. Overall, the two linguistic cues did not combine to increase speech intelligibility scores significantly over either cue alone. However, for Speaker One (least severe) the combination of cues provided a significant increase over letter cues alone. All speakers were shown to benefit from the use of supplemental linguistic cues, although the degree of benefit afforded by the cuing conditions differed for speaker severity. Analysis of the interaction between semantic cue and severity level suggested that for Speaker One, listeners received the most benefit from the use of either semantic cues alone or in combination with letter cues to assist in understanding this speaker. Either of the two linguistic cuing conditions alone (letter cue or semantic cue) were shown to benefit the two speakers (Two and Three) in the most severe categories of dysarthria. Analysis of the interaction among letter cue, semantic cue and speaker severity indicated that for the speakers used in this study, no minimum level of speech intelligibility appeared necessary to benefit from the use of linguistic cuing.

6.1 Clinical Implications

From a clinical perspective these results supported the view that patient management decisions relating to the use of supplemental linguistic cues should be made on a case-by-case basis. For a number of reasons it is likely that the use of letter cues will continue to be the first choice of speakers and clinicians to augment word identification. This cuing method uses a closed set of 26 familiar items that can provide an initial linguistic cue and then, if needed, be used to spell out a complete word that has not been understood. In this study, subjects consistently used the letter cue correctly in their attempts to predict single words. This is in contrast to their reduced ability to use contextual information provided by the semantic cues appropriately. In many instances listeners were unable to use the semantic cues to advantage, sometimes guessing words that did not correspond to the grammatical category provided. Perhaps with more practice in the use of semantic cues listeners would learn to use this information more effectively to supplement the distorted speech signal. However, a training requirement would likely limit the use of semantic cues to familiar trained partners rather than to a wider group of incidental conversational partners.

Further, while the use of semantic cues would be dependent on a closed set of grammatical categories, the subset of noun categories may require frequent change, depending on the topic of conversation and the activity in which the speaker is involved. The speaker may require a number of semantic cuing sheets for each activity and speaking partner. Decisions concerning the most appropriate cuing method for a given speaker would be dependent on these considerations.

Based on previous research evidence, the single word task was selected as a valid procedure appropriate for measuring the speech intelligibility of speakers with severe dysarthria. However, listening to a series of unrelated words proved to be a challenge for the subjects, even with the addition of supplemental linguistic cues. All speakers received higher intelligibility scores on the sentence test, hence it is possible that a sentence based task would have resulted in a greater enhancement of the listeners' ability to understand the speakers. The word task may have underestimated the functional intelligibility of the three speakers.

Questions about the clinical utility of the supplemental linguistic cues remain to be investigated. It is of interest that the combined cuing condition, which provided the most contextual information, gave the greatest assistance to the most rather than least intelligible speaker. Based on these results it appears that the fifth hypothesis tested, that a minimum level of speaking ability is required for supplemental cues to be of benefit, should be qualified as follows: There is a minimum level of intelligibility for these cues to be of maximal benefit. Replicating this study with more speakers would help to identify whether these results are idiosyncratic to this speaker or consistent across severely dysarthric speakers. The role of the semantic cue in this cuing model needs further analysis to determine its benefit when used with trained and untrained listeners. It would also be helpful to know whether the benefit of a linguistic cue increases within a setting that is more typical of conversational interactions.

6.2 Internal Validity

Every effort was made to control for factors affecting the internal validity of the study. Extraneous factors that could account for the results were minimized by random selection and allocation of subjects to groups, and the careful manipulation of independent variables to control for extraneous variables affecting the dependent variable. Ventry and Schiavetti (1980) describe the factors that affect internal validity as history, maturation, test practice effects, instrumentation, statistical regression, differential selection of subjects, mortality, and interaction of factors.

6.2.1 Instrumentation. Three instrumentation issues should be discussed: recording conditions, selection of speaker to represent severity level, and balancing

grammatical categories within word lists. A previous description of the recording procedures alluded to some of the challenges clinicians face when attempting to obtain high quality recordings from speakers who are severely disabled. Moreover, idiosyncratic behaviours of speakers can affect the consistency of recording standards across speakers. For instance, saliva build up from Speaker One, nasal emission from Speaker Two, and occasional excessive bursts of sound from Speaker Three may have resulted in some distortion of the sound quality on the audio track compared with the live transmission of the words. However, because listeners heard the same audio track in all four experimental conditions, they were subjected in equal measure to these noise factors.

A description of the methods used to identify speaker severity levels has highlighted the possibility that the designation of three levels was inappropriate and that it would have been more suitable to designate two speaker severity levels. Based on this assumption Speakers Two and Three may be said to fall within the same severity level, thus limiting the comparisons that can be drawn for speakers in the most severe classifications (severe & profound). As noted, statistical analysis of results for Speakers Two and Three revealed comparable results across all cuing conditions for these speakers.

Rank ordering of semantic categories revealed that nouns appeared to be the easiest grammatical category for listeners to identify. While this study did not attempt to address the issue of whether certain grammatical categories were more effective than others, the influence of different grammatical categories on listeners' ability to identify words should be considered in future research. Such an effect could be controlled by using word lists containing an equal number of exemplars within each grammatical category represented. This lack of balance can be considered a threat to the internal validity of this study.

6.2.2 Maturation Effect. A maturation effect posed a further possible threat to the internal validity of the study. It is possible that, due to the challenging nature of the task, some subjects experienced short term inattention or fatigue. Every effort was made to counteract the effects of fatigue. The duration of the listening task was short (35 minutes in length) and subjects were provided with one minute breaks after each set of 25 words. Maturation effects were also minimized by the random selection and assignment of subjects to groups. However, it is possible that effects of fatigue and inattention could have been further minimized by counterbalancing the order of words for subjects.

6.2.3 Statistical Regression. Consideration should also be given to the effects of statistical regression on the outcome of the study. Speakers were selected based on the results of sentence test scores. Recordings for the sentence material and the experimental single word material were carried out on two separate occasions. It is possible that variability in speaker performance affected

the scores and that one performance may have been atypical for that speaker. Although test-retest variability data were taken into consideration when designating speaker severity levels, it may be more appropriate to consider recording material for the selection criteria and the experimental task during the same recording session or, if conducted on two separate occasions, using a split-half method. The split-half method would counteract speaker variability by combining half of the material recorded on the first session with the remainder of the set taken from the second recording session.

6.3 External Validity

The generalizability of the findings are limited because of the exploratory nature of the study. This is the first systematic investigation of the effects of linguistic cues on the ability of listeners to identify single words spoken by severely dysarthric speakers. Since the factors affecting the internal validity of the study were carefully controlled it may be possible to generalize the findings in a limited way to similar subjects listening to the same severely dysarthric speakers. To generalize these findings with confidence to a larger population would necessitate replicating the study using larger groups of speakers within each severity level, with listeners who are both familiar and unfamiliar with the speech of dysarthric individuals.

6.4 Further Research

This study has identified further areas for continued research. It would be of benefit to replicate the results of this study using larger groups of dysarthric speakers per severity level in order to carefully examine the predictive relationship between sentence and single word intelligibility scores as a means of ranking such speakers. Future studies should also address the method of placing speakers in severity levels by using a more conservative approach in delimiting the placement of speakers into categories based on sentence test scores. A wider point score difference than was used in this study may be necessary to unequivocally differentiate between speaker severity levels. Another clinical extension of this study would be to identify methods to investigate and measure the effectiveness of dysarthric speakers using cuing techniques with listeners in interactive tasks that more closely resemble typical communication situations.

CHAPTER VII

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CHAPTER VIII

APPENDIX A

Paired-Word Intelligibility Test*
(Listed by Phonetic Contrast)

Contrast	Examples of Word Pairs
Initial voiced vs. voiceless	bee-pee, do-two, goo-coo
Final voiced vs. voiceless	add-at, buzz-bus, need-neat
Vowel duration long vs. short	eat-it, gas-guess, pop-pup
Stop vs. fricative	see-tea, sew-toe, do-zoo
Glottal vs. null	high-eye, hit-it, has-as
Fricative vs. affricate	shoe-chew, shop-chop, ship-chip
Stop vs. nasal	dough-no, bee-me, buy-my
Alveolar vs. palatal	see-she, sew-show, sip-ship
Tongue height high vs. low	eat-at, soup-soap, eat-eight
Tongue advancement front vs. back	hat-hot, tea-two, day-dough
Stop-place	
labial vs. alveolar	bow-dough
labial vs. velar	pan-can
alveolar vs. velar	dough-go
Diphthong	buy-boy, high-how, aisle-oil

Liquid/Place	ray-lay, rip-lip, raw-law
Glide/Liquid	way-ray, row-woe, won-run
Liquid vs. vowel	string-stirring, spring-spurring, bring-burring
Cluster with one intrusive vowel	blow-below, plight-polite, claps-collapse

*Kent, Weismer, Kent and Rosenbek, 1989

APPENDIX B

Master List of Stimulus Words and Semantic Cues
(Divided by Speaker)

SPEAKER ONE

for	conjunction
trade	noun - miscellaneous
hear	verb
loop	noun - shape
kitten	noun - animal
cart	noun - transportation
nest	noun - animal
quicker	descriptor
fork	noun - utensil
shed	noun - building
reap	verb
timber	noun - plant
sort	verb
wives	noun - people
stable	noun - building
vamp	noun - miscellaneous
ban	verb
phone	noun - household
Spain	noun - name
wall	noun - building
mold	noun - miscellaneous
teach	verb
rage	noun - emotion
lisp	noun - miscellaneous
rut	noun - miscellaneous
conserve	verb
depress	verb
store	verb
boot	noun - clothing
grove	noun - outside place
waste	verb
wit	noun - miscellaneous
wire	noun - tool
shoe	noun - clothing
car	noun - transportation
honest	descriptor

flaw	noun - miscellaneous
below	preposition
mate	noun - people
denture	noun - body part
by	conjunction
design	verb
least	descriptor
batter	verb
street	noun - outside place
art	noun - hobby
grape	noun - food
jade	noun - miscellaneous
page	noun - school
we're	noun - pronoun

Summary of Speaker One's Word List by Grammatical Category

Descriptors	3
Verbs	11
Nouns	33
Conjunctions	2
Prepositions	1

SPEAKER TWO

floor	noun - building
rain	noun - weather
mere	descriptor
whoop	verb
bitten	verb
hark	verb
best	descriptor
sicker	descriptor
fork	noun - utensil
shed	noun - building
beat	verb
tender	descriptor
form	noun - miscellaneous
why	descriptor
saddle	noun - animal
ramp	noun - building
boat	noun - transportation

file	noun - work
Spain	noun - name
owl	noun - animal
sold	verb
neat	descriptor
range	noun - miscellaneous
less	descriptor
bust	noun - body part
deserve	verb
depress	verb
torch	noun - tool
booth	noun - building
gross	descriptor
brace	verb
stiff	descriptor
wire	noun - tool
shot	noun - miscellaneous
carp	verb
option	noun - miscellaneous
boss	noun - people
coal	noun - fuel
late	descriptor
creature	noun - animal
ride	verb
divide	verb
leak	verb
mother	noun - people
grind	verb
park	noun - outside place
gang	noun - people
may	verb
pace	noun - miscellaneous
hear	verb

Summary of Speaker Two's Word List by Grammatical Category

Descriptors	10
Verbs	15
Nouns	25

SPEAKER THREE

warm	descriptor
train	noun - transportation
steer	noun - animal
root	noun - plant
hitting	verb
park	noun - outside place
rest	verb
slicker	noun - clothing
cork	noun - miscellaneous
fed	verb
neat	descriptor
ember	noun - miscellaneous
born	descriptor
wide	descriptor
Mabel	noun - name
bat	noun - animal
ban	verb
final	descriptor
paid	verb
fall	verb
bull	noun - animal
preach	verb
range	noun - outside place
limb	noun - body part
musk	noun - miscellaneous
super	descriptor
contact	verb
shore	noun - outside place
boot	noun - clothing
grove	noun - outside place
waste	verb
twist	verb
wise	descriptor
sharp	descriptor
pear	noun - food
honest	descriptor
law	noun - miscellaneous
sew	verb
rake	noun - tool
creature	noun - animal
tie	noun - clothing
defeat	verb

lip	noun - body part
brother	noun - people
scream	noun - emotion
park	noun - outside place
great	descriptor
faint	verb
cage	noun - container
spear	noun - weapon

Summary of Speaker Three's Word List by Grammatical Category

Descriptors	10
Verbs	13
Nouns	27

TABLE VIII-1. Frequency of Occurrence of Grammatical Categories in Master Word List.

	GRAMMATICAL CATEGORY				
	Noun	Verb	Descriptor	Conjunction	Preposition
Total	85	39	23	2	1
Percentage Total Words in Master List	57%	26%	15%	1%	1%